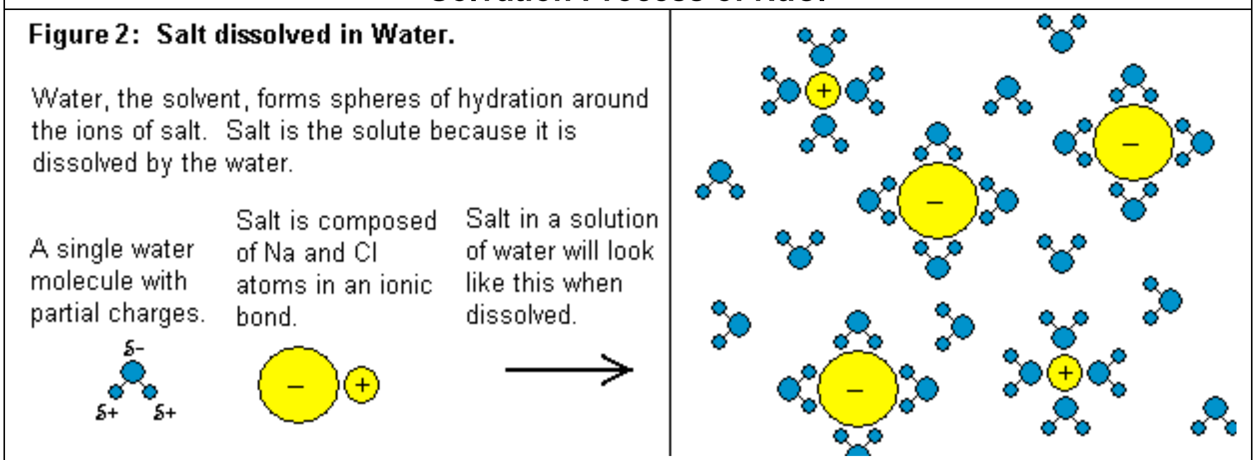
Solubility Curve of Sugar in Water

INTRODUCTION

Solutions are homogeneous mixtures of **solvents** (the larger volume of the mixture) and **solutes** (the smaller volume of the mixture). For example, a hot chocolate is a solution, in which the solute (the chocolate powder) is dissolved in the solvent (the milk or water). The solute and solvent can be a solid, liquid, or a gas. A solution forms when the attractive forces between the solute and the solvent are similar. For example, the ionic or polar solute, NaCl, dissolves in water, a polar solvent. The phrase “like dissolves like” has often been used to explain this.

As the water molecules collide with the ionic compound (NaCl), the charged ends of the water molecule become attracted to the positive sodium ions (Na^+) and negative chloride ions (Cl^-). The water molecules surround the ions and the ions move into solution. This process of attraction between the water molecules (the solvent) and the ionic compound (NaCl), the solute) is called **solvation**.

Solvation Process of NaCl



http://homepages.ius.edu/GKIRCHNE/Water.htm

Some solutions form quickly and others form slowly. The rate depends upon several factors, such as, the size of solute, stirring, or heating. When making hot chocolate, we stir chocolate powder into hot milk or water. When a solution holds a maximum amount of solute at a certain temperature, it is said to be **saturated**. If we add too much chocolate powder to the hot milk, the excess solute will settle on the bottom of the container. Generally, the chocolate powder dissolves better in hot milk than cold milk. Thus, heating the solution can increase the amount of solute that dissolves. Most solids are more soluble in water (solvents) at higher temperatures.

Solubility is the quantity of solute that dissolves in a given amount of solvent. The solubility of a solute depends on the nature of the solute and solvent, the amount of solute, the temperature and pressure (for a gas) of the solvent.

Solubility is expressed as the quantity of solute per 100 g of solvent at a specific temperature.

LEARNING OBJECTIVES

Students will:
- compare data using a graph (M1.1)
- construct and interpret a solubility curve (3.1xxv)
- use solubility curves to distinguish among saturated, unsaturated, and supersaturated solutions (3.1xxviii)
- use collision theory to explain how temperature influences the solubility of sugar (3.4vi)

MATERIALS

Balance	Thermometer	Hot plate
Spatula	Stirring rod	10 mL graduated cylinder
Test tubes	Ring stand	Test tube holder and rack
1L Beaker	Utility clamp	Sugar
Distilled water	Marking pencil	

HAZARD INFORMATION:

Chemical Name	Health Hazards	Physical Hazards	Environmental Hazards
Sugar	Low hazard	Low hazard	Low hazard
Distilled Water	Low hazard	Low hazard	Low hazard

WASTE

Description of Material (include concentration)	Quantity per student	Hazard	Disposal Method
Sugar solution <10M	<50mL	Low	Drain Disposal with excess water

PROCEDURE

1. Using label tape, number four test tubes (1-4) and place them into a test tube rack.

2. Using a balance and weigh boat, measure the first test tube of sugar as indicated below:

Do Not Place Sugar Into Test Tube!

Test Tube #	Mass of Sugar (g)	Volume of distilled H_2O (mL)
1	12.5	5
2	14.0	5
3	15.0	5
4	16.0	5

3. Fill a 1 L beaker about ¾ full of tap water. This will be used as a hot water bath. Place the water bath on the hot plate (set to medium temperature). Place test tube #1, containing only the 5mL of water, in the utility clamp and attach the clamp to the ring stand. Lower the test tube into the hot water bath. Slowly add small amounts of sugar to the test tube. Dissolve added sugar before adding more. Continue heating the water bath until the temperature reaches 90°C and adjust the heat to maintain this temperature.

4. Stir the sugar/water mixture with a glass stirring rod until the sugar is completely dissolved. Loosen the clamp and, using a test tube holder, remove the tube. Continuously stir the sugar solution until the first signs of **crystallization** is observed. Record the temperature immediately as crystallization begins in the data table.

5. Repeat Steps 3 and 4 for all four test tubes. One partner should complete step 3 while the other is completing step 4. Record all temperatures in the data table.

CLEANUP: Pour the solutions of table sugar and water into the drain. Carefully wash the test tubes, beaker, and thermometer until all sugar is removed. If sugar is difficult to remove, test tubes may be soaked in warm water.

Student Name:____________________ Date: ____________________

Observations

Data Summary

Fill in the following table with the data gathered from the experiment.

Test Tube #	**Mass of Sugar/Volume of H_2O**	**Crystallization Temperature (°C)**	**Mass of sugar/100 mL of H_2O (g/100 mL H_2O)**
1	12.5g/5 mL		
2	14.0g/5 mL		
3	15.0g/5 mL		
4	16.0g/5 mL		

Create a graph of mass percent of sugar vs. crystallization temperature. Attach the graph. You will need it to answer the questions for this lab.

Lab Questions

1. According to your graph, how does the solubility of sugar change as the temperature increases?

2. Explain, at the molecular level, why this relationship exists between temperature and solubility.

3. **Using your graph**, how many grams of sugar can be dissolved in 100 mL water at the following temperatures?

    a. 20°C ________

    b. 40°C ________

    c. 60°C ________

    d. 80°C ________

    e. 90°C ________

4. **On your solubility curve**, what is the change in solubility from 30°C to 60°C? Show your work!

5. **Using your graph**, how much sugar must be added to make a saturated solution at 55°C?

6. Define the terms saturated, unsaturated and supersaturated. Use your graph to explain these terms.

7. Some of the water may have evaporated from the test tubes before their saturation temperatures were measured. What effect would this error have on the solubility of sugar for a solution? Would the corresponding saturation temperature be too high or too low as a result of this error? What changes would take place in your graph?

8. All thermometers have "lag time" (it takes a little while to register or report a temperature change). What effect would this error have on the solubility of sugar for a solution? Would the corresponding saturation temperature be too high or too low as a result of this error? What changes would take place in your graph?

Green Question(s)

9. This experiment is typically run using potassium nitrate or potassium chloride. What are the hazards of potassium nitrate and potassium chloride? Compare these hazards to the hazards for sugar.

References

Holmquist, D., Randall, J. & Volz, D. (2007). *Chemistry with Vernier : chemistry experiments using Vernier sensors*. Beaverton: Vernier Software & Technology.

University of Manitoba Center For Research in Youth, Science Teaching, and Learning. Chemistry Teaching Resources: Solubility Curve Lab. http://umanitoba.ca/outreach/crystal/resources%20for%20teachers/SolubilityCurveLab.doc.

TEACHER INFORMATION

Regents Core

This is a green method for students to create their own solubility curve. It demonstrates the concepts of solubility, solubility curves, dissolution, and collision theory.

Teacher Tips

-Adding 3mL of water, dissolving the sugar, and then adding the last 2mL of water at the end to wash down any sugar trapped on the sidewalls of the test tube may help maintain consistent results.

-Students should be careful with stirring the solution or the bottom wall of the test tube can break.

-The tubes will be extremely concentrated and hot. Take care that students do not burn themselves

-In order to speed the process up, multiple test tubes can be used so that all 4 trials can be heated at once.

- Turn the hot water baths on before class to reduce the lab time used to heat the water.

- Make sure that students do not add the sugar to the test tube first. It makes the experiment take much longer

- Test tubes can be saved for a few lab periods by wrapping with parafilm.

- A room temperature water bath **with constant stirring** can be used to speed up the process.

Preparation:

Provide a lab setup for each group. Distilled water should be used for the experiment. Tap water can be used in the beaker for the hot water bath. Much of the experiment can be set up by the students.

Sample Data:

Answers to Questions

1. According to your graph, how does the solubility of sugar change as the temperature increases? Solubility increases as temperature increases

2. Explain, at the molecular level, why this relationship exists between temperature and solubility. Increased temperatures increases molecular motion of the solvent. This will increase interactions between the solvent and the solute, allowing more solute to be dissolved.

3. **Using your graph**, how many grams of sugar can be dissolved in 100 mL water at the following temperatures? Dependent on Student Data

   a. 20°C ________

   b. 40°C ________

   c. 60°C ________

   d. 80°C ________

   e. 90°C ________

4. **On your solubility curve**, what is the change in solubility from 30°C to 60°C? Show your work! Dependent on student data. Solubility will increase.

5. **Using your graph**, how much sugar must be added to make a saturated solution at 55°C? Dependent on student data.

6. Define the terms saturated, unsaturated and supersaturated. Use your graph to explain these terms.

   Saturated: The point of maximum concentration, where no more solute can be dissolved in the solution.

   Unsaturated: A point where the amount of solute dissolved in a solution is less than the maximum amount of solute possibly dissolved in the solution.

   Supersaturated: Containing an amount of solute that is greater than the theoretical maximum amount of solute capable of being dissolved in a solution at a given temperature.

7. Some of the water may have evaporated from the test tubes before their saturation temperatures were measured. What effect would this error have on the solubility of sugar for a solution? Would the corresponding saturation temperature be too high or too low as a result of this error? What changes would take place in your graph?

   Evaporation will increase the concentration of the solution, causing a decrease in the observed solubility of the sugar. The corresponding saturation temperature will be too high, because the increased concentration will cause the solute to fall out of solution sooner than expected. This would move the graph up.

8. All thermometers have "lag time" (it takes a little while to register or report a temperature change). What effect would this error have on the solubility of sugar for a solution? Would the corresponding saturation temperature be too high or too low as a result of this error? What changes would take place in your graph?

   The "lag time" would cause a false recording of temperature that is higher than the actual temperature. This would result in a saturation temperature that is too high, recording a lower level of solubility. (ex. 12.5g of sugar would dissolve in 5mL of H_2O at 60°C instead of 58°C, looking like a higher temperature was needed) This would move the entire graph higher on the y-axis.

WASTE

Chemical Name	CAS Number	Health Hazards	Physical Hazards	Environmental Hazards
Sugar Solution	57-50-1	Low Hazard	Low Hazard	Low Hazard

1. How has this lab been modified to make it "greener"?

This experiment is typically done with Potassium Nitrate or Potassium Chloride. Potassium Nitrate is acutely and chronically toxic to aquatic life and an oxidizer. Potassium Chloride is acutely and chronically toxic to aquatic life. In this experiment, sugar was used instead. Sugar is a low hazard compound that

exhibits a similar solubility curve to both Potassium Nitrate and Potassium Chloride.

2. Which of the 12 principles of Green Chemistry were employed to make this lab greener?

Please check all that apply.

⊗ **Prevention** It's better to prevent waste than to treat or clean up waste afterwards.

❍ **Atom Economy** Design synthetic methods to maximize the incorporation of all materials used in the process into the final product.

❍ **Less Hazardous Chemical Syntheses** Design synthetic methods to use and generate substances that minimize toxicity to human health and the environment.

❍ **Designing Safer Chemicals** Design chemical products to affect their desired function while minimizing their toxicity.

❍ **Safer Solvents and Auxiliaries** Minimize the use of auxiliary substances wherever possible make them innocuous when used.

❍ **Design for Energy Efficiency** Minimize the energy requirements of chemical processes and conduct synthetic methods at ambient temperature and pressure if possible.

⊗ **Use of Renewable Feedstocks** Use renewable raw material or feedstock rather whenever practicable.

❍ **Reduce Derivatives** Minimize or avoid unnecessary derivatization if possible, which requires additional reagents and generate waste.

❍ **Catalysis** Catalytic reagents are superior to stoichiometric reagents.

❍ **Design for Degradation** Design chemical products so they break down into innocuous products that do not persist in the environment.

❍ **Real-time Analysis for Pollution Prevention** Develop analytical methodologies needed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

⊗ **Inherently Safer Chemistry for Accident Prevention** Choose substances and the form of a substance used in a chemical process to minimize the potential for chemical accidents, including releases, explosions, and fires.[1]

[1] Retrieved from http://www.epa.gov/sciencematters/june2011/principles.htm